US009214655B2

(12) **United States Patent**
Watanabe et al.

(10) **Patent No.: US 9,214,655 B2**
(45) **Date of Patent: Dec. 15, 2015**

(54) **POWER STORAGE DEVICE**

(75) Inventors: **Hirotaka Watanabe**, Toyota (JP); **Masahiro Imai**, Miyoshi (JP)

(73) Assignees: **Toyota Jidosha Kabushiki Kaisha**, Toyota-shi, Aichi-ken (JP); **Kojima Press Industry Co., Ltd**, Toyota-shi, Aichi-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 248 days.

(21) Appl. No.: **13/992,257**

(22) PCT Filed: **Dec. 12, 2011**

(86) PCT No.: **PCT/IB2011/002993**

§ 371 (c)(1),
(2), (4) Date: **Jun. 7, 2013**

(87) PCT Pub. No.: **WO2012/080805**

PCT Pub. Date: **Jun. 21, 2012**

(65) **Prior Publication Data**

US 2013/0273397 A1 Oct. 17, 2013

(30) **Foreign Application Priority Data**

Dec. 15, 2010 (JP) 2010-278859

(51) **Int. Cl.**

H01M 2/10	(2006.01)
H01M 10/615	(2014.01)
H01M 10/6557	(2014.01)
H01M 10/6561	(2014.01)
H01M 10/6566	(2014.01)
H01M 10/613	(2014.01)
H01M 10/647	(2014.01)

(52) **U.S. Cl.**

CPC ***H01M 2/1016*** (2013.01); ***H01M 2/1022*** (2013.01); ***H01M 2/1072*** (2013.01); ***H01M 2/1077*** (2013.01); ***H01M 10/613*** (2015.04); ***H01M 10/615*** (2015.04); ***H01M 10/6557*** (2015.04); ***H01M 10/6561*** (2015.04); ***H01M 10/6566*** (2015.04); *H01M 10/647* (2015.04)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,444,348	B1	9/2002	Saijo et al.
6,761,992	B1	7/2004	Markukawa et al.
2005/0084743	A1	4/2005	Okamoto et al.
2005/0130033	A1	6/2005	Iwamura et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP	2001-68081	3/2001
JP	2002-42753	2/2002

(Continued)

OTHER PUBLICATIONS

Applicant's Communication in International Application No. PCT/IB2011/002993 (Jul. 10, 2012).

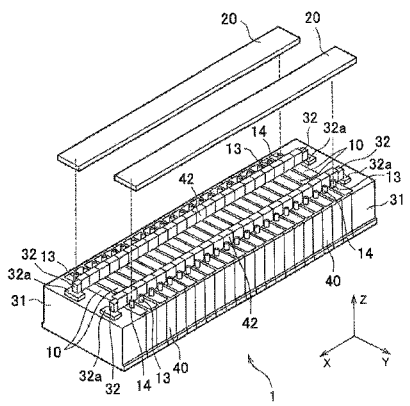
Primary Examiner — Cynthia K Walls

(74) *Attorney, Agent, or Firm* — Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

(57) **ABSTRACT**

A power storage device includes a plurality of power storage elements (**10**) lined up along a predetermined arrangement direction; a dividing member (**40**) that is made of insulating material and arranged between two adjacent power storage elements; a pair of end plates (**31**) that sandwich the plurality of power storage elements, and apply restraining force thereto, in the arrangement direction; and a metal connecting member (**32**) that extends in the arrangement direction and is fixed to the pair of end plates. The dividing member includes a retaining portion (**42**) that is positioned between the power storage elements and the connecting member, and that retains the connecting member.

15 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0104927	A1	4/2010	Albright
2010/0112424	A1	5/2010	Hayashi
2010/0167115	A1	7/2010	Okada et al.

FOREIGN PATENT DOCUMENTS

JP	2003-346754	12/2003
JP	2004-22338	1/2004
JP	3595346	12/2004
JP	2007-280858	10/2007
JP	2008-16259	1/2008
JP	2008-103248	5/2008
JP	2008-159439	7/2008
JP	2008-192551	8/2008
JP	2008-277085	11/2008
JP	2009-21067	1/2009
JP	2009-259455	11/2009
JP	2010-157450	7/2010
JP	2010-257652	11/2010
WO	WO 99/40637 A1	8/1999

FIG. 1

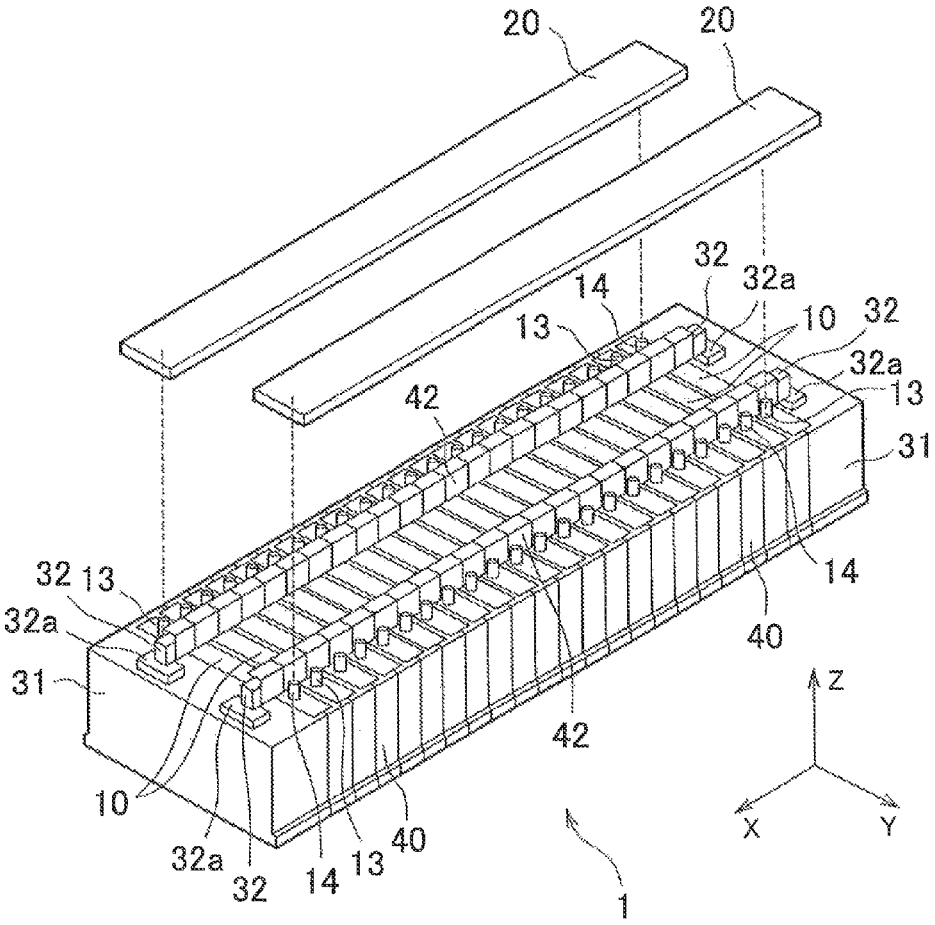

20
20
32
32a
14
13
10
32
32a
13
42
31
32 13
32a
31
14
40
42
10
32a
32
14
13
40
1
Z
X
Y

FIG. 2

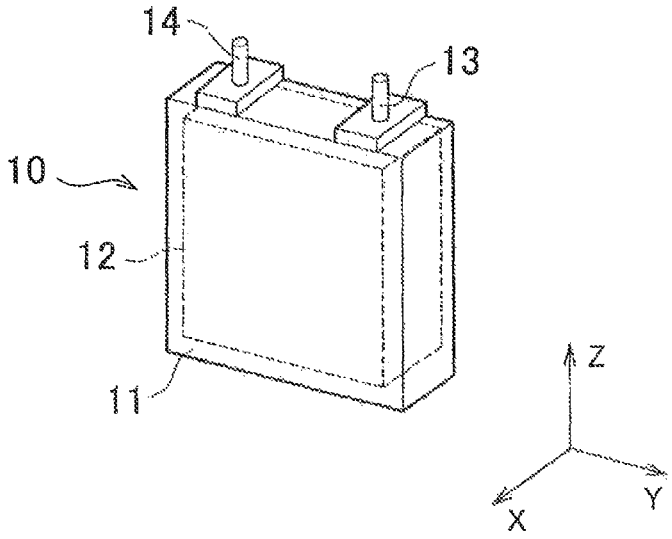


FIG. 3

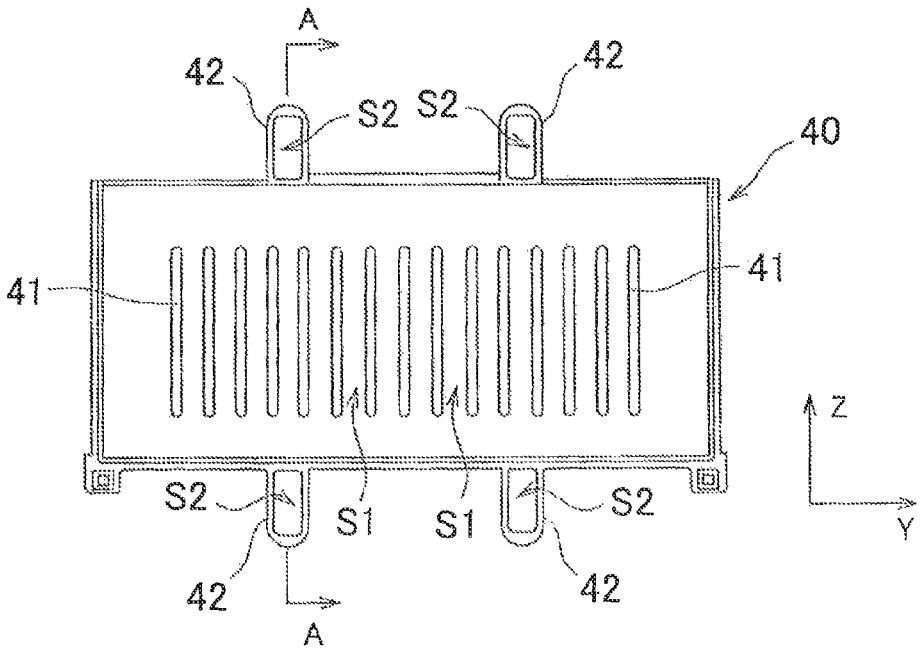


FIG. 4

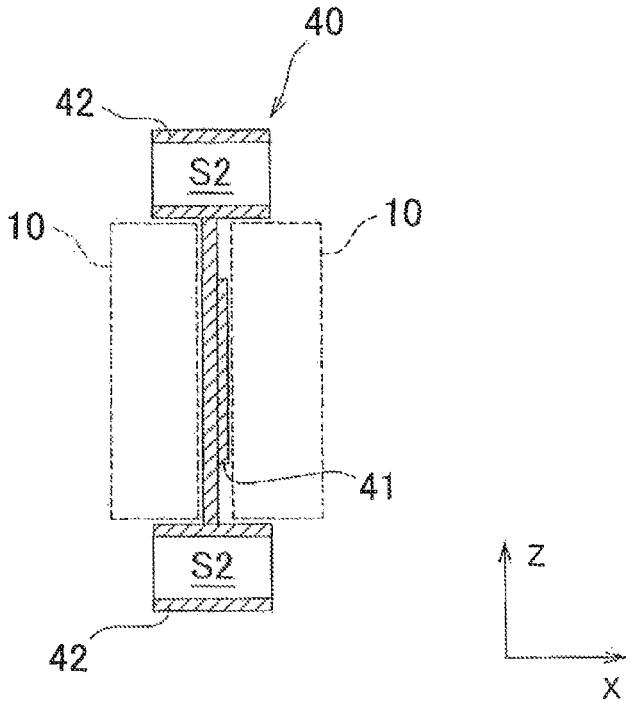

40
42
S2
10
10
41
S2
42
Z
X

FIG. 5

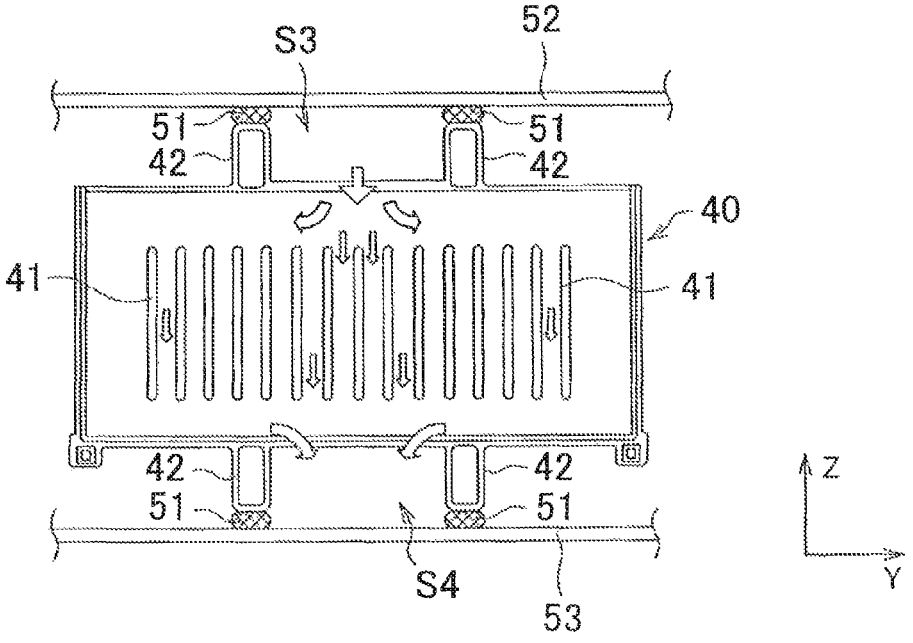

S3
52
51
51
42
42
40
41
41
42
42
51
51
S4
53
Z
Y

FIG. 6

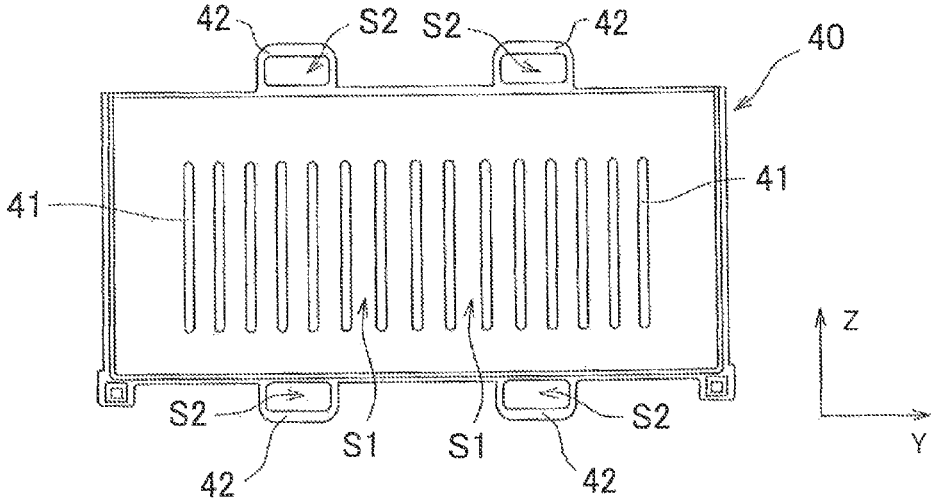

42
S2
S2
42
40
41
41
S2
S2
S1
S1
42
42
Z
Y

FIG. 7

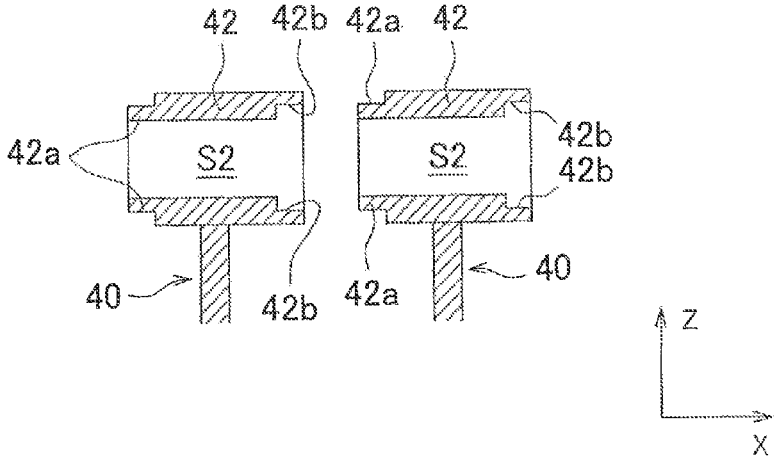

42
42b
42a
42
42a
S2
S2
42b
42b
40
42b
42a
40
Z
X

FIG. 8

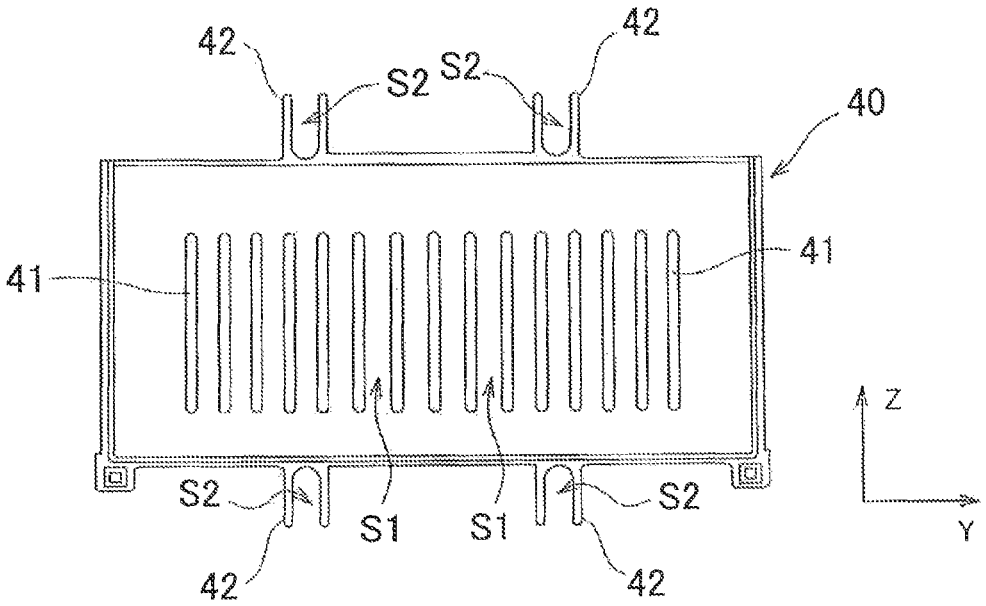

42
S2
S2
42
40
41
41
Z
S2
S1
S1
S2
Y
42
42

FIG. 9

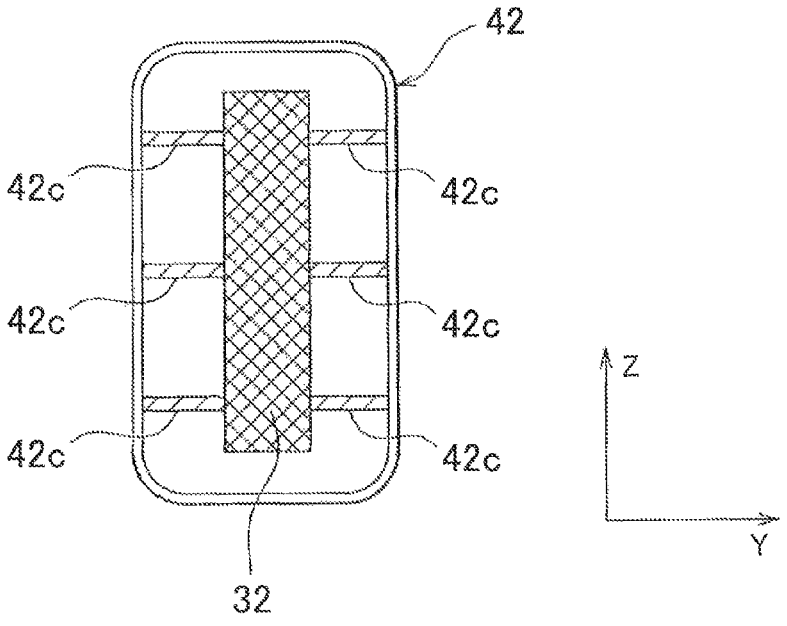

42
42c
42c
42c
42c
42c
42c
Z
Y
32

FIG. 10

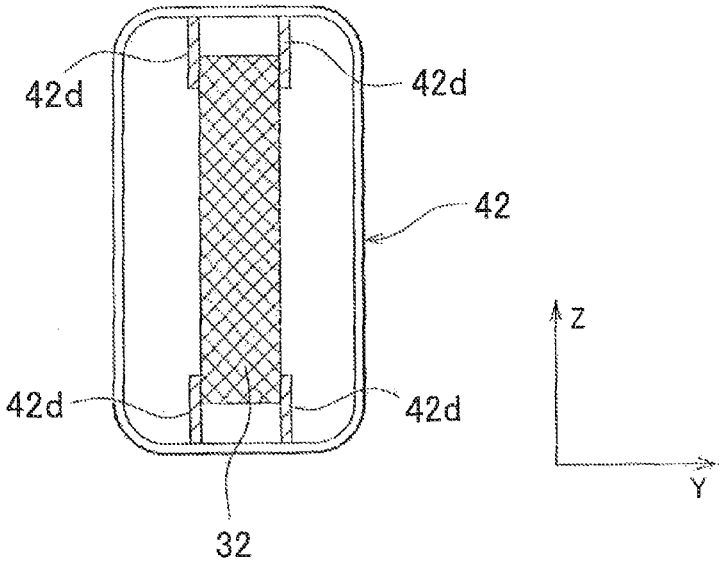


FIG. 11

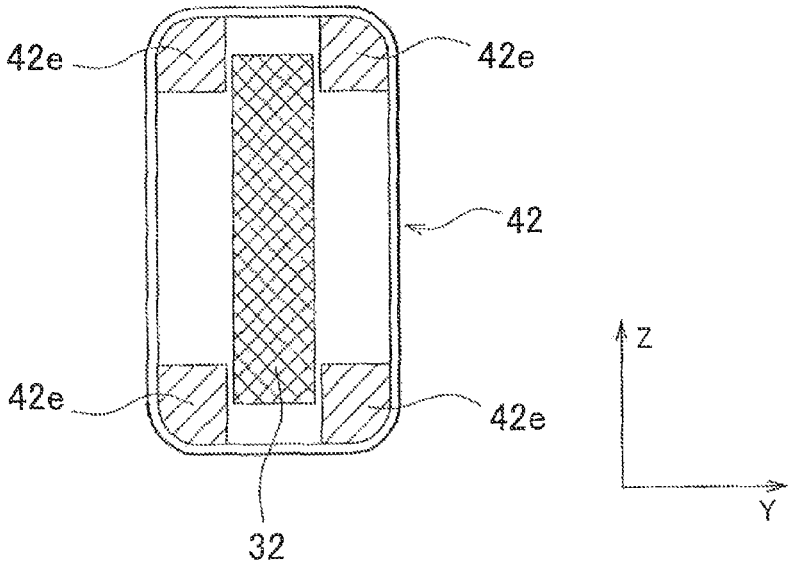


FIG. 12

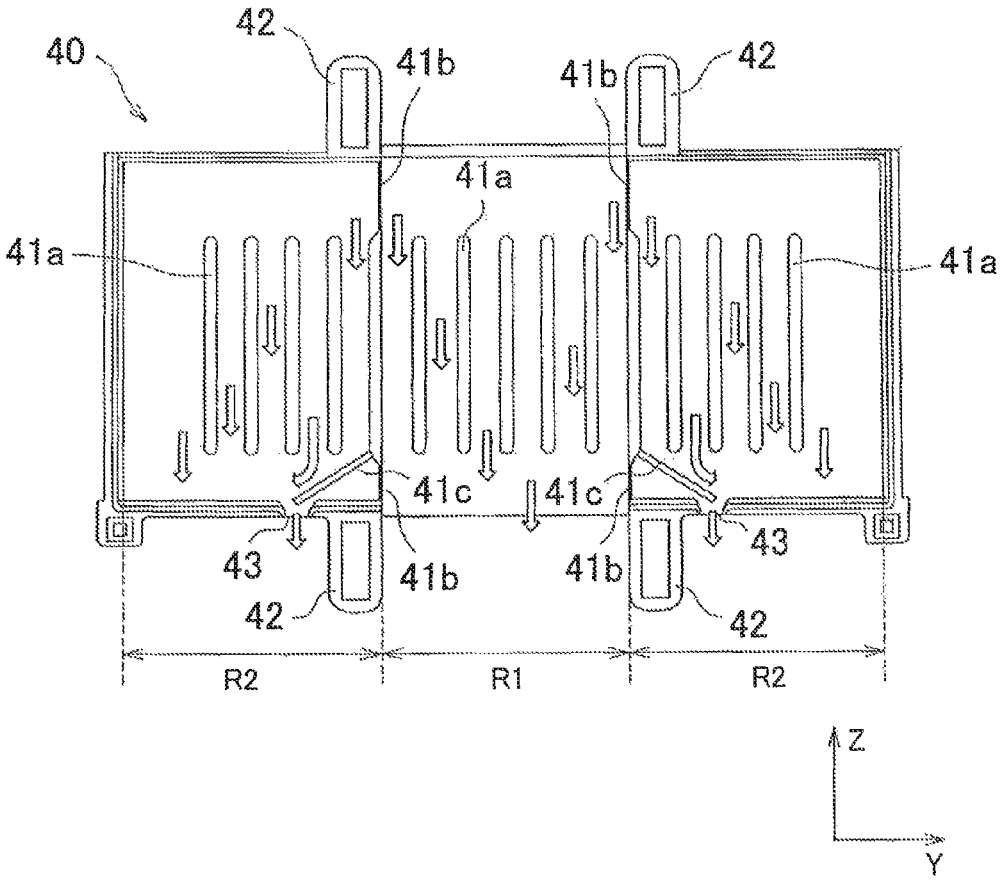


FIG. 13

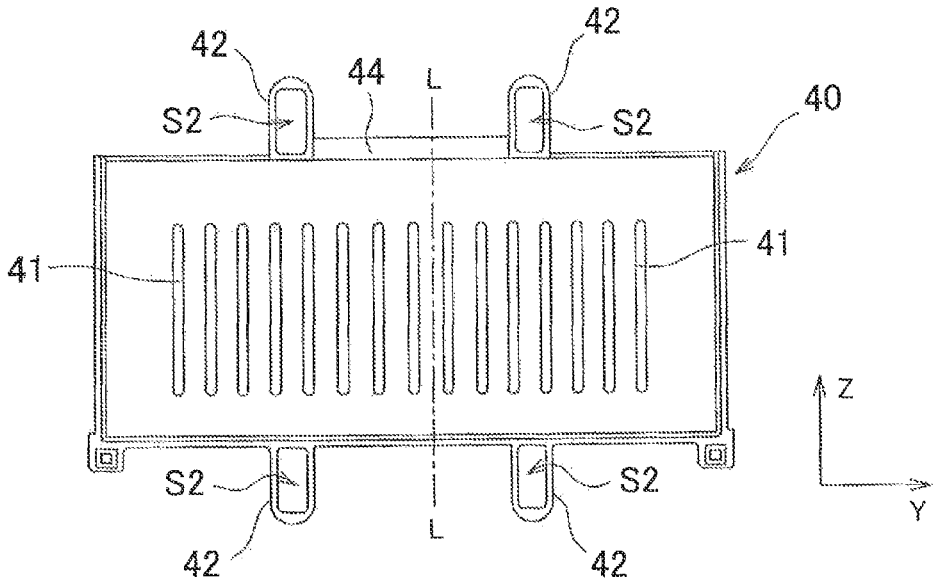
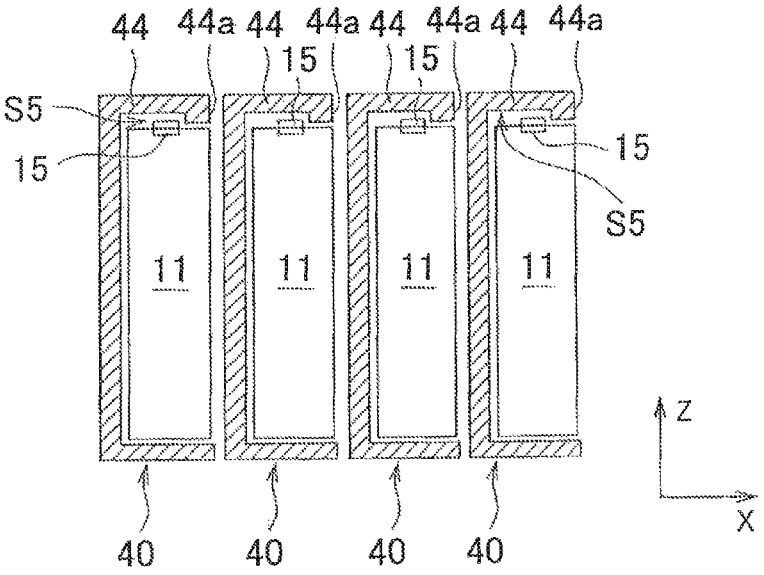

42
42
44
L
S2
S2
40
41
41
Z
S2
S2
Y
L
42
42

FIG. 14


44
44a
44
44a
44
44a
44
44a
15
15
S5
15
15
S5
11
11
11
11
Z
40
40
40
40
X

POWER STORAGE DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national phase application of International Application No. PCT/IB2011/002993, filed Dec. 12, 2011, and claims the priority of Japanese Application No. 2010-278859, filed Dec. 15, 2010, the content of both of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a power storage device that includes a mechanism that applies restraining force to a plurality of power storage elements arranged lined up in one direction.

2. Description of Related Art

Technology is known in which a battery pack is formed by lining up a plurality of single cells in one direction. Also, restraining force is applied to the plurality of single cells using a restraining mechanism. The restraining force is force that squeezes the plurality of single cells together in the direction in which they are arranged (hereinafter referred to as the "arrangement direction").

The restraining mechanism includes a pair of end plates that sandwich the plurality of single cells, and a band that is fixed to the pair of end plates. The band extends in the arrangement direction of the plurality of single cells, and is able to apply restraining force to the plurality of single cells by the ends of the band being fixed to the pair of end plates.

In the restraining mechanism described above, the band is sometimes formed of metal in order to ensure restraining force with respect to the single cells. In this case, it is preferable to ensure that the band is insulated from the single cells. More specifically, an insulating member is preferably provided between band and the single cells. However, when an insulating member is provided between the band and the single cells, the number of parts ends up increasing.

SUMMARY OF THE INVENTION

One aspect of the invention relates to a power storage device. This power storage device includes a plurality of power storage elements lined up along a predetermined arrangement direction; a dividing member that is made of insulating material and arranged between two adjacent power storage elements; a pair of end plates that sandwich the plurality of power storage elements, and apply restraining force thereto, in the arrangement direction; and a metal connecting member that extends in the arrangement direction and is fixed to the pair of end plates. The dividing member includes a retaining portion that is positioned between the power storage elements and the connecting member, and that retains the connecting member.

In this aspect, the retaining portion of the two dividing members that are adjacent in the arrangement direction may contact each other while lined up along the connecting member. Also, the retaining portion may surround the connecting member in a plane orthogonal to the arrangement direction. According to this structure, all of the surfaces of the connecting member are able to be covered by the retaining portion of a plurality of dividing members.

Also, in the structure described above, the retaining portion may be formed in a shape that follows an outer surface of the connecting member. According to this structure the connecting member can be covered without increasing the size of the retaining portion. Also, in the structure described above, the retaining portion may include a protruding portion that sandwiches the connecting member, on an inner wall surface that faces the connecting member. According to this structure, a plurality of retaining portions can be positioned with respect to the connecting member.

Moreover, in the structure described above, two of the retaining portions that are adjacent in the arrangement direction may each include an engaging portion that engages with each other, and each engaging portion may include a surface that extends in the arrangement direction. According to this structure, the contact area of two retaining portions can be increased, and foreign matter such as water droplets can be inhibited from getting into the retaining portion (i.e., the arranging space of the connecting member).

Also, in the structure described above, a flow path for a heat exchange medium that can be used to regulate the temperature of the power storage elements may be formed using the retaining portion and a case that forms an exterior of the power storage device. Gas or fluid may be used as the heat exchange medium. Air may be used as the gas. The heat exchange medium flow passage may be an intake passage for supplying heat exchange medium to the power storage elements, or a discharge passage for discharging heat exchange medium after heat exchange. Accordingly to this structure, forming the passage for the heat exchange medium enables the chamber for forming a passage for the heat exchange medium can be omitted, and thus enables the number of parts to be reduced.

Moreover, in the structure described above, a guide rib (**41***c*) that guides foreign matter headed toward the retaining portion away from the retaining portion may be provided on the dividing member. According to this structure, foreign matter is able to be inhibited from reaching the retaining portion. The two retaining portions only contact one another, so it is possible that foreign matter may end up getting into the connecting portion of the two retaining portions. Using the guide rib thus enables foreign matter to be inhibited from getting in.

In the structure described above, a drain hole for draining the foreign matter guided by the guide rib outside the dividing member may be formed in the dividing member. According to this structure, foreign matter can be efficiently discharged outside the dividing member.

In the structure described above, when the power storage elements each include a valve for discharging gas produced inside the power storage elements, a cover that protrudes to a position facing the valve and covers the valve may be provided on the dividing member. According to this structure, the valve can be protected by using the cover. In the structure described above, the cover may include a region away from the valve, and a tip end portion that extends toward the valve. According to this structure, a space between the cover and the valve can be ensured by extending the tip end portion of the cover toward the valve.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. **1** is an external view of a battery pack according to a first example embodiment of the invention;

FIG. **2** is an external view of a single cell according to the first example embodiment;

FIG. **3** is a front view of a dividing member according to the first example embodiment;

FIG. **4** is a sectional view taken along line A-A in FIG. **3**, of the dividing member according to the first example embodiment;

FIG. **5** is a view of an intake passage and a discharge passage according to the first example embodiment;

FIG. **6** is a front view of a dividing member according to a modified example of the first example embodiment;

FIG. **7** is a view of the structure of a portion of a dividing member according to another modified example of the first example embodiment;

FIG. **8** is a front view of a dividing member according to yet another modified example of the first example embodiment;

FIG. **9** is a view of the internal structure of a housing portion according to a second example embodiment of the invention;

FIG. **10** is a view of the internal structure of a housing portion according to a modified example of the second example embodiment;

FIG. **11** is a view of the internal structure of a housing portion according to another modified example of the second example embodiment;

FIG. **12** is a front view of a dividing member according to a third example embodiment of the invention;

FIG. **13** is a front view of a dividing member according to a fourth example embodiment of the invention; and

FIG. **14** is a sectional view of the battery pack when cut along line L-L in FIG. **13**.

DETAILED DESCRIPTION OF EMBODIMENTS

A battery pack **1** according to a first example embodiment of the invention will now be described with reference to FIG. **1**. FIG. **1** is an external view of the battery pack of this example embodiment. In FIG. **1**, the X axis, the Y axis, and the Z axis are orthogonal to each other. In this example embodiment, the Z axis is an axis that corresponds to the vertical direction. The relationships among the X axis, the Y axis, and the Z axis are the same for the other drawings as well. The battery pack **1** may serve as the power storage device of the invention.

The battery pack **1** has a plurality of single cells **10**. The plurality of single cells **10** are lined up in the X direction. The number of single cells **10** may be set appropriately based on the required output and the like of the battery pack **1**. Secondary batteries such as nickel-metal hydride batteries or lithium ion batteries may be used for the single cells **10**. Also, electric double layer capacitors (capacitors) may be used instead of secondary batteries. In this example embodiment, the plurality of single cells **10** are lined up in the X direction, but the invention is not limited to this. More specifically, a plurality of single cells **10** may be used to form a single battery module, and a plurality of battery modules may be lined up in the X direction. The single cells **10** may serve as the power storage elements of the invention.

As shown in FIG. **2**, each single cell **10** includes a battery case **11** and a power generating element **12** housed in the battery case **11**. The power generating element **12** is an element that charges and discharges. The power generating element **12** may be formed by a positive element, a negative element, and a separator (including an electrolyte solution) arranged between the positive element and the negative element. A solid electrolyte may also be used instead of the electrolyte solution. The positive element forms a layer that includes positive active material, on a surface of a collector plate. The negative element forms a layer that includes negative active material, on a surface of the collector plate.

A positive element **13** and a negative element **14** are provided on an upper surface of the battery case **11** in the Z direction. The positive element **13** is electrically connected to the positive element of the power generating element **12**. The negative element **14** is electrically connected to the negative element of the power generating element **12**.

The plurality of single cells **10** that are arranged lined up in the X direction are electrically connected in series. More specifically, the positive element **13** of one single cell **10** is electrically connected to the negative element **14** of another single cell **10** by the bus bar. Also, the negative element **14** of one single cell **10** is electrically connected to the positive element **13** of another single cell **10** by a bus bar. In this example embodiment, two bus bar modules **20** are used to electrically connect the plurality of single cells **10** together. Each bus bar module **20** has a plurality of bus bars and a resin plate that supports the plurality of bus bars.

A pair of end plates **31** are arranged, one at each end of the battery pack **1** in the X direction. A band **32** that extends in the X direction is fixed to the pair of end plates **31**. The band **32** is made of metal. In this example embodiment, two bands **32** are arranged on the upper surface of the battery pack **1** in the Z direction. Also, although not shown in FIG. **1**, two bands **32** are also arranged on the lower surface of the battery pack **1** in the Z direction. Fixing portions **32***a* provided on both ends of each band **32** are fixed to the end plates **31**. The method by which the end plates **31** are fixed to the fixing portions **32***a* may be fastening using bolts, for example. The band **32** may serve as the connecting member of the invention.

Restraining force may be applied to the plurality of single cells **10** that form the battery pack **1** by fixing the bands **32** to the pair of end plates **31**. The restraining force is force that squeezes the plurality of single cells **10** together in the X direction. Applying restraining force to the single cells **10** makes it possible to inhibit the single cells **10** from expanding.

In this example embodiment, two bands **32** are arranged on the upper surface of the battery pack **1** in the Z direction and two bands **32** are arranged on the lower surface of the battery pack **1** in the Z direction, but the invention is not limited to this. The number of bands **32** that are arranged on the upper and lower surfaces of the battery pack **1** in the Z direction may be set appropriately. That is, the number of bands **32** is not limited as long as restraining force is able to be applied to the single cells **10** by fixing the bands **32** to the pair of end plates **31**.

A dividing member **40** is arranged between two adjacent single cells **10** in the X direction. The dividing member **40** may be formed by insulating material such as resin, such that two adjacent single cells **10** in the X direction are insulated from each other.

FIG. **3** is a view of the dividing member **40** from the X direction, and FIG. **4** is a sectional view taken along line A-A in FIG. **3**.

The dividing member **40** has a plurality of ribs **41** that protrude in the X direction. The plurality of ribs **41** are provided on a wall surface of the dividing member **40** that faces the single cell **10** in the X direction. That is, the plurality of ribs **41** are provided protruding in the arrangement direction of the power storage elements, on a wall surface of the dividing member that faces the power storage element. Each rib **41** extends in the Z direction, and the plurality of ribs are lined up in the Y direction. The length of each of the plurality of ribs **41** is shorter than the length of the dividing member in the Z

direction, i.e., the vertical direction. The tip ends of the ribs **41** in the X direction contact the single cell **10**, such that spaces S**1** are formed between the dividing member **40** and the single cell **10**. The spaces S**1** are spaces through which air for regulating the temperature of the single cell **10** flows. The air may serve as the heat exchange medium of the invention.

The ribs **41** are formed only on one wall surface of the dividing member **40**. The wall surface on side opposite the wall surface on which the ribs **41** are formed is formed by a flat surface. In other words, in a structure in which a dividing member **40** is sandwiched between two single cells **10**, the ribs **41** are formed on a wall surface of the dividing member **40** that faces one of the single cells **10**, and the ribs **41** are not formed on the wall surface of the dividing member **40** that faces the other single cell **10**. It should be noted, however, that ribs may also be formed on the wall surfaces of the dividing member **40** that face two single cells **10**.

The single cells **10** positioned on both ends of the battery pack **1** in the X direction are each sandwiched between a dividing member **40** and an end plate **31**. Of the two end plates **31**, one end plate **31** has ribs corresponding to the ribs **41**.

The ribs **41** extend in the Z direction. Air for regulating the temperature (i.e., temperature regulating air) advances in the Z direction along the dividing member **40**. For example, when supplying temperature regulating air from the Upper surface of the battery pack **1** in the Z direction, this air advances from the upper portion toward the lower portion of the dividing member **40**. When air flows through the spaces S**1**, heat exchange is performed between the air and the single cell **10**, thus enabling the temperature of the single cell **10** to be regulated. The air after the temperature has been regulated is then led to a discharge passage provided in the lower surface of the battery pack **1** in the Z direction. On the other hand, when temperature regulating air is supplied from the lower surface of the battery pack **1** in the Z direction, this air advances from the lower portion toward the upper portion of the dividing member **40**. The air after the temperature has been regulated is then led to a discharge passage provided in the upper surface of the battery pack **1** in the Z direction.

When the single cell **10** is producing heat, a rise in the temperature of the single cell **10** can be suppressed by leading air for cooling (i.e., cooling air) into the spaces S**1**. Also, when the single cell **10** is too cold, a decrease in temperature of the single cell **10** can be suppressed by leading air for heating (i.e., heating air) into the spaces S**1**. Maintaining the temperature of the single cell **10** within a predetermined temperature range makes it possible to inhibit the input/output characteristics of the single cell **10** from deteriorating.

In this example embodiment, air is used to regulate the temperature of the single cell **10**, but the invention is not limited to this. That is, a gas other than air may be used, or a liquid may be used. If a liquid is used, an insulating liquid is preferably used. Also, when a liquid is used, the passage through which the liquid flows must be sealed.

Two housing portions **42** are provided on the upper portion of the dividing member **40**, and two housing portions **42** are provided on the lower portion of the dividing member **40**. The housing portions **42** each have a space S**2** through which the corresponding band **32** passes (see FIG. **1**). The space S**2** is formed in a shape that follows the outer shape of the band **32**. Each of these housing portions **42** may serve as a retaining portion of the invention.

As shown in FIG. **4**, the housing portions **42** extend in the X direction. When two dividing members **40** are lined up in the X direction, the housing portions **42** of one dividing member **40** contact the housing portions **42** of the other dividing member **40**. Connecting the housing portions **42** of the plurality of dividing members **40** together enables the bands **32** that extend in the X direction to be covered by the plurality of housing portions **42**.

A manufacturing method of the battery pack **1** of this example embodiment will now be briefly described. First, the single cells **10** and the dividing members **40** are alternately arranged. Accordingly, the housing portions **42** of the plurality of dividing member **40** can be connected together and the bands **32** can be passed through the connected plurality of housing portions **42**. Both ends of each of the bands **32** protrude from the passages formed by the housing portions **42**, so the bands **32** can be fixed to the end plates **31** by the fixing portions **32***a*.

In this example embodiment, passages that cover the bands **32** can be formed by simply lining up the dividing members **40**. Also, insulation of the bands **32** can be ensured by the housing portions **42** that are formed by insulating material coy the bands **32**. The housing portions **42** are part of the dividing members **40**, so the plurality of dividing members **40** can be arranged along the bands **32** by passing the bands **32** through the housing portions **42**.

Meanwhile, as shown in FIG. **5**, passages for moving the temperature regulating air can be formed using the housing portions **42**. An intake passage S**3** for supplying temperature regulating air is provided above the dividing members **40**. This intake passage S**3** extends in the X direction, and is formed by the two housing portions **42** and an upper case **52**. The upper case **52** forms the exterior of the battery pack **1** and, together with a lower case **53** that will be described later, covers the single cells **10** and the dividing members **40**. The upper case **52** and the lower case **53** may be made of metal such as aluminum. A seal member **51** is arranged between each housing portion **42** and the upper case **52**.

As shown by the arrows in FIG. **5**, air that flows through the intake passage S**3** flows to the spaces S**1** formed between the dividing member **40** and the single cell **10**, where it flows along the ribs **41**. The air that flows through the spaces S**1** flows to a discharge passage S**4** provided below the dividing member **40**. This discharge passage S**4** extends in the X direction and is formed by the two housing portions **42** and the lower case **53**. A seal member **51** is arranged between each housing portion **42** and the lower case **53**.

Forming the intake passage S**3** and the discharge passage S**4** using the housing portions **42** enables the number of parts to be reduced, which in turn enables the battery pack **1** to be made smaller. With the structure shown in FIG. **5**, the intake passage S**3** is provided above the dividing member **40** and the discharge passage S**4** is provided below the dividing member **40**, but the invention is not limited to this. More specifically, the discharge passage S**4** may be provided above the dividing member **40** and the intake passage S**3** may be provided below the dividing member **40**. In this case, the direction in which the air flows is opposite the direction shown by the arrows in FIG. **5**.

In this example embodiment, as shown in FIG. **3**, the length of the spaces S**2** of the housing portions **42** in the Z direction is longer than the length of the spaces S**2** of the housing portions **42** in the Y direction. The invention is not limited to the structure shown in FIG. **3**. That is, the structure shown in FIG. **6** is also possible. In the structure shown in FIG. **6**, the length of the spaces S**2** of the housing portions **42** in the Y direction is longer than the length of the spaces S**2** of the housing portions **42** in the Z direction.

Also in this example embodiment, the bands **32** in which the cross-section orthogonal to the length direction is rectangular are used, but the invention is not limited to this. For example, rods having circular cross-sections may be used

instead of the bands **32**. In this case, the inner wall surfaces of the housing portions **42** that form the spaces S2 may be formed in shapes that follow the outer peripheries of the rods. The spaces S2 do not have to be formed in shapes that follow the bands **32**. That is, the spaces S2 may be any shape as long as the bands **32** are able to pass through them. A rod may serve as the connecting member of the invention.

In this example embodiment, the end portions of the housing portions **42** in the X direction are formed with a flat surface, but the invention is not limited to this. For example, the housing portions **42** may have the structure shown in FIG. **7**. In FIG. **7**, a protruding portion **42***a* is formed on one end of the housing portion **42** in the X direction, and a recessed portion **42***b* is formed on the other end of the housing portion **42** in the X direction. When two of the dividing members **40** are lined up, the protruding portion **42***a* of one housing portion **42** engages with the recessed portion **42***b* of the other housing portion **42**. The protruding portion **42***a* and the recessed portion **42***b* may serve as the engaging portion of the invention.

If the structure shown in FIG. **7** is used, two adjacent dividing members **40** in the X direction can be easily connected together by inserting the protruding portion **42***a* of one housing portion **42** into the recessed portion **42***b* of the other housing portion **42**. Also, using the protruding portion **42***a* and the recessed portion **42***b* enables the contact area of the two housing portions **42** to be increased. As a result, the flow of water or the like at the contact portion of the two housing portions **42** can be suppressed, so the insulating property of the band **32** can be improved.

With the structure shown in FIG. **7**, the protruding portion **42***a* and the recessed portion **42***b* are formed on opposite ends of the housing portion **42** in the X direction, but the invention is not limited to this. For example, a dividing member **40** that has protruding portions **42***a* on both ends of the housing portion **42** in the X direction, and a dividing member **40** that has recessed portions **42***b* on both ends of the housing portion **42** in the X direction may be used. In this case, the plurality of housing portions **42** may be connected together so as to form passages that cover the bands **32**, by arranging the two type of dividing members **40** alternately.

The structure that connects two housing portions **42** is not limited to the structure shown in FIG. **7**. The end portions of the housing portions **42** in the X direction may be formed with three-dimensional (X, Y, and Z) surfaces instead of being formed by only surfaces in the Y-Z planes. More specifically, of the two housing portions **42**, portions that engage together need only have surfaces that extend in the X direction. A surface that extends in the X direction may be a surface that follows the X axis, or a surface that is sloped with respect to the X axis. This kind of structure enables two adjacent housing portions **42** in the X direction to be easily connected, as well as makes it possible to ensure the contact area of the two housing portions **42**, and inhibit water or the like from getting in.

With this example embodiment, the bands **32** are arranged on the upper and lower surfaces of the battery pack **1** in the Z direction, but the invention is not limited to this. More specifically, the bands **32** may be arranged on both side surfaces of the battery pack **1** in the Y direction. The bands **32** need only connect the pair of end plates **31** together. The positions in which the bands **32** are arranged may be set as appropriate. Also, the positions of the housing portions **42** provided on the dividing members **40** may be changed according to the positions of the bands **32**.

With this example embodiment, the housing portions **42** surround the bands **32** within the Y-Z planes, but the invention is not limited to this. That is, the bands **32** may also be retained and insulated from the single cells **10** using a portion of the dividing member **40**. More specifically, the structure shown in FIG. **8** may be employed. FIG. **8** is a view of the structure of a dividing member **40** that corresponds to FIG. **3**.

As shown in FIG. **8**, retaining portions **42** are provided on both the upper and lower surfaces of the dividing member **40** in the Z direction. The retaining portions **42** have the same function as the housing portions **42** described in this example embodiment. The retaining portions **42** have three surfaces corresponding to the bands **32** in the Y-Z plane, and so do not surround the bands **32**. With the structure shown in FIG. **8** as well, the bands **32** are able to be insulated from the single cells **10**. Here, the shapes of the retaining portions **42** in the Y-Z plane may be set as appropriate.

Meanwhile, with the example embodiment, two adjacent housing portions **42** in the X direction contact one another, but the invention is not limited to this. More specifically, the two housing portions **42** may be separated from each other in the X direction. Also, in this example embodiment, two adjacent housing portions **42** in the X direction contact one another along their entire end surfaces in the X direction, but the invention is not limited to this. More specifically, two housing portions **42** may contact one another at only a portion of their end surfaces in the X direction.

Next, a battery pack according to a second example embodiment of the invention will be described. Members in this example embodiment that have the same function as members described in the first example embodiment will be denoted by like reference characters, and detailed descriptions of these members will be omitted. Hereinafter, mainly the differences from the first example embodiment will be described.

As described in the first example embodiment, after all of the dividing members **40** have been lined up in the X direction, the bands **32** are passed through the plurality of housing portions **42** that are connected together. In this example embodiment, the bands **32** extend in the X direction, so the plurality of housing portions **42** are positioned based on the bands **32**. That is, the plurality of dividing members **40** are inhibited from becoming offset, based on the bands **32**.

In this example embodiment, protruding portions are provided on the inner wall surfaces of the housing portions **42**, so the plurality of housing portions **42** are positioned based on the bands **32**. The structures shown in FIGS. **9** to **11** are also conceivable as structures that provide protruding portions on the inner wall surfaces of the housing portions **42**. FIGS. **9** to **11** are enlarged views (that correspond to FIG. **3**) of a housing portion **42** viewed from the X direction. Although FIGS. **9** to **11** show a housing portion **42** provided on an upper portion of the dividing member **40**, the housing portion **42** provided on the lower portion of the dividing member **40** is the same.

The structures shown in FIGS. **9** to **11** are only examples. Other structures are also possible as long as protruding portions that contact the bands **32** are provided inside the housing portions **42**.

In the structure shown in FIG. **9**, a plurality of protruding portions **42***c* that protrude in the Y direction are provided on the inner wall surface of the housing portion **42**. The plurality of protruding portions **42***c* are arranged in positions sandwiching the band **32** housed in the housing portion **42**. The plurality of protruding portions **42***c* arranged on both sides of the band **32** are lined up in the Z direction.

The number of protruding portions **42***c* arranged on both sides of the band **32** may be set as appropriate. Here, as shown in FIG. **9**, the number of protruding portions **42***c* arranged on one side of the band **32** may be the same as the number of

protruding portions **42***c* arranged on the other side of the hand **32**. Alternatively, the number of protruding portions **42***c* arranged on one side of the band **32** may be different from the number of protruding portions **42***c* arranged on the other side of the band **32**.

In the structure shown in FIG. **10**, a plurality of protruding portions **42***d* that protruded in the Z direction are provided on the inner wall surface of the housing portion **42**. A pair of protruding portions **42***d* arranged on the upper portion of the housing portion **42** sandwich the band **32** in the Y direction. Also, a pair of protruding portions **42***d* arranged on the lower portion of the housing portion **42** sandwich the band **32** in the Y direction. The housing portion **42** is able to be positioned along the band **32** using these two pairs of protruding portions **42***d*.

In the structure shown in FIG. **11**, a protruding portion **42***e* is provided on each of the four corner portions of the housing portion **42**. The two protruding portions **42***e* positioned on the upper side of, the housing portion **42** are arranged in positions sandwiching the band **32** in the Y direction, and the two protruding portions **42***e* positioned on the lower side of the housing portion **42** are arranged in positions sandwiching the band **32** in the Y direction. The housing portion **42** is able to be positioned along the band **32** using these four protruding portions **42***e*.

Next, a battery pack according to a third example embodiment of the invention will be described. Members in this example embodiment that have the same function as members described in the first example embodiment will be denoted by like reference characters, and detailed descriptions of those members will be omitted. Hereinafter, mainly the differences from the first and second example embodiments will be described.

FIG. **12** is a view of the dividing member **40** used in this example embodiment as viewed from the X direction. The dividing member **40** has first ribs **41***a* and second ribs **41***b*. The first ribs **41***a* correspond to the ribs **41** described in the first example embodiment and extend in the Z direction. Neither end of the first ribs **41***a* in the Z direction extends to the outer edge of the dividing member **40**.

The second ribs **41***b* protrude in the X direction, and the tip ends of the second ribs **41***b* in the X direction contact the single cell **10**. Also, the second ribs **41***b* extend to the upper and lower portions of the dividing member **40**, and divide the dividing member **40** into three regions R**1** and R**2**. The first region R**1** is a region that is sandwiched between two second ribs **41***b*, and forms a space through which temperature regulating air flows. The arrows shown in the first region R**1** indicate the direction in which air flows. Also, in the first region R**1**, a plurality of first ribs **41***a* are lined up in the Y direction. A plurality of the first ribs **41***a* are also lined up in the Y direction in the second regions R**2** as well.

The second regions R**2** are regions that are surrounded by a second rib **41***b* and the outer edge of the dividing member **40**. Temperature regulating air does not enter these second regions R**2**. That is, the spaces corresponding to the second regions R**2** are surrounded by the dividing member **40** and the single cell **10**. Also, a drain hole **43** is formed in the lower portion of the dividing member **40** in each second region R**2**. This drain hole **43** may be used to drain water droplets out of the dividing member **40**, as will be described later.

A guide rib **41***c* is provided in each second region R**2**. This guide rib **41***c* protrudes in the X direction, and a tip end of the guide rib **41***c* in the X direction contacts the single cell **10**. Also, the guide rib **41***c* is positioned above the housing portion **42** provided on the lower portion of the dividing member **40**, and is slanted with respect to the Z direction. More specifically, one end of the guide rib **41***c* that is positioned above is connected to the second rib **41***b*, and the other end of the guide rib **41***c* that is positioned below is positioned above the drain hole **43**.

Condensation may form in the second region R**2** depending on the outside environment, such as the air temperature and humidity. If condensation forms, water droplets may run downward and reach the housing portion **42** provided on the lower portion of the dividing member **40**. As described in the first example embodiment, two adjacent housing portions **42** in the X direction are only contacting one another, so it is possible that the water droplets may end up getting into the connecting portion of the two housing portions **42**.

In this example embodiment, water droplets are led away from the housing portion **42** using the guide rib **41***c*. As a result, it is possible to inhibit water droplets from getting into the connecting portion of the two housing portions **42**. In FIG. **12**, the arrows shown in the second regions R**2** indicate the direction in which the water droplets run. When water droplets adhere to the second region R**2** of the dividing member **40**, they run downward along the first ribs **41***a* and the second rib **41***b*. In the region where the guide rib **41***c* is not provided, water droplets fall onto the lower portion of the dividing member **40**. Meanwhile, water droplets that have reached the guide rib **41***c* run along the guide rib **41***c* and are led to the drain hole **43**. As a result, water droplets pass through the drain hole **43** and are drained out of the dividing member **40**.

In this example embodiment, the guide rib **41***c* is formed in the shape shown in FIG. **12**, but the invention is not limited to this as long as the water droplets that fall onto the housing portion **42** can be led away from the housing portion **42**. Based on this, the shape of the guide rib **41***c* can be set as appropriate.

Next, a battery pack according to a fourth example embodiment of the invention will be described. Members in this example embodiment that have the same function as members described in the first example embodiment will be denoted by like reference characters, and detailed descriptions of those members will be omitted. Hereinafter, mainly the differences from the first example embodiment will be described. FIG. **13** is a view of a dividing member **40** used in this example embodiment when viewed from the X direction, and FIG. **14** is a sectional view of the battery pack when cut along line L-L in FIG. **13**.

A safety valve **15** is provided on the upper surface of a battery case **11** in the Z direction. This safety valve **15** is used to discharge gas produced inside the battery case **11** outside of the battery case **11**. When gas is produced inside the battery case **11**, the pressure inside the battery case **11** rises. In response, the safety valve **15** changes from closed to open, such that the gas can be discharged outside of the battery case **11**. This safety valve **15** may serve as the valve of the invention.

A so-called destruction valve or a so-called return type valve may be used as the safety valve **15**. A destruction valve is a valve that plastically deforms from closed to open, and does not return from open to closed. A return type valve is a value that changes between closed and open according to the internal pressure and external pressure of the battery case **11**.

The dividing member **40** has a cover **44**. As shown in FIG. **13**, the cover **44** is positioned between the two housing portions **42** provided on the upper portion of the dividing member **40**, and is connected to these two housing portions **42**. Also, the cover **44** protrudes in the X direction and covers the safety valve **15** provided on the upper surface of the single cell **10** in the Z direction. A tip end portion **44***a* of the cover **44**

extends downward, such that a space S5 is formed between the safety valve **15** and the cover **44**.

The space S5 becomes a space when the safety valve **15** is operated. If the cover **44** is too close to the safety valve **15**, the cover **44** will prevent the safety valve **15** from operating, making it difficult for the safety valve **15** to change from closed to open. In this example embodiment, operation of the safety valve **15** is ensured by providing the space S5.

According to this example embodiment, the safety valve **15** is able to be protected by providing the cover **44**. For example, the cover **44** can prevent temperature regulating air from directly reaching the safety valve **15**. As described in the first example embodiment, the temperature regulating air flows between the dividing member **40** and the single cell **10**. For example, the air is able to flow from the lower portion toward the upper portion of the dividing member **40**, or able to flow from the upper portion toward the lower portion of the dividing member **40**. In this type of structure, the air would directly reach the safety valve **15** if the cover **44** were not provided.

The space S5 is able to be formed by having the cover **44** be away from the safety valve **15**, so the tip end portion **44***a* of the cover **44** does not need to extend downward. If the tip end portion **44***a* extends downward as it does in this example embodiment, then when external force is applied to the cover **44**, the tip end portion **44***a* will contact the upper surface of the single cell **10** in the Z direction, so that the space S5 can continue to be ensured.

The invention claimed is:

1. A power storage device comprising:

a plurality of power storage elements lined up along a predetermined arrangement direction;

a dividing member that is made of insulating material and arranged between two adjacent power storage elements;

a pair of end plates that sandwich the plurality of power storage elements, and apply restraining force thereto, in the arrangement direction; and

a metal connecting member that extends in the arrangement direction and is fixed to the pair of end plates, wherein

the dividing member includes a retaining portion that is positioned between the power storage elements and the connecting member, and that retains the connecting member, wherein

the retaining portion surrounds the connecting member in a plane orthogonal to the arrangement direction, and wherein

the retaining portions of the two dividing members that are adjacent in the arrangement direction contact each other while lined up along the connecting member.

2. The power storage device according to claim **1**, wherein the retaining portion is formed in a shape that follows an outer surface of the connecting member.

3. The power storage device according to claim **1**, wherein two of the retaining portions that are adjacent in the arrangement direction each have an engaging portion that engages with each other, and each engaging portion includes a surface that extends in the arrangement direction.

4. The power storage device according to claim **1**, wherein the retaining portion includes a protruding portion that sandwiches the connecting member, on an inner wall surface of the retaining portion that faces the connecting member.

5. The power storage device according to claim **1**, further comprising a case that forms an exterior of the power storage device, wherein the retaining portion and the case form a flow passage for a heat exchange, medium used to regulate a temperature of the power storage elements.

6. The power storage device according to claim **1**, wherein the dividing member includes a guide rib that guides foreign matter headed toward the retaining portion away from the retaining portion.

7. The power storage device according to claim **6**, wherein the dividing member includes a drain hole for draining the foreign matter guided by the guide rib outside the dividing member.

8. The power storage device according to claim **1**, wherein the power storage elements each have a valve for discharging gas produced inside the power storage elements, and the dividing member includes a cover that protrudes to a position facing the valve and covers the valve.

9. The power storage device according to claim **8**, wherein the cover includes a region away from the valve, and a tip end portion that extends toward the valve.

10. The power storage device according to claim **1**, further comprising fixing portions provided on both ends of the connecting member, wherein the connecting member is fixed to the end plates by the fixing portions.

11. The power storage device according to claim **1**, wherein the dividing member includes a plurality of ribs, and the plurality of ribs are provided protruding in the arrangement direction of the power storage elements, on a wall surface of the dividing member that faces the power storage elements.

12. The power storage device according to claim **11**, wherein of the end plates, one end plate includes ribs that correspond to the plurality of ribs provided on the dividing member.

13. The power storage device according to claim **11**, wherein a vertical length of the plurality of ribs is shorter than a vertical length of the dividing member.

14. The power storage device according to claim **1**, wherein the retaining portion defines a passage, and the connecting member is at least partially disposed within the passage.

15. The power storage device according to claim **1**, wherein the connecting member is positioned on a top surface of the power storage device.

* * * * *